CONVERSION OF LINE RECORDS TO DIGITAL INFORMATION

A thesis submitted

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for the Degree of

MASTER OF TECHNOLOGY

BY

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CERTIFICATE

This is to certify that the work for this Thesis has been carried out under my supervision and this work has not been submitted elsewhere for a Degree.

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CONTENTS

SYNOPSIS

We often have to convert the ordinate values of curves to digital numbers so that digital computers can be used for the analysis of the curves.

A system was developed for this purpose. A scanning head that has a photoconductive cell scans the record. The change in the light reflected from the paper when a dark line is encountered by the scan head is detected by the photo cell. A counter that always has a number that is proportional to the displacement of the scan head along the y-direction, is interrogated when the line is detected and the number is stored in a register. The system at present is meant for records with a single value for each point on the abscissa.

In the y-direction there are 128 levels of quantisation. In the x-direction the levels of quantisation can be either 256 or 512. About 20 samples per cm. of the record can be had at 256 quantisations and twice as many at 512 levels.

The number that is in the register can be written on magnetic tape at the end of every scan. The tape unit is IBM compatible and the tape format is suitable for processing on IBM 7044 Computer.

CHAPTER I

INTRODUCTION

In the course of normal scientific activity deductions and inferences regarding the process under study are made with the help of observations. These observations often pertain to changes in various physical, chemical and physiological parameters with time. For example these may be changes in pressure temperature, voltage etc. with time. These observations when they are large in number, are recorded and the data thus obtained are analysed later.

Data is sometimes recorded on strip charts or photographic paper with the varying parameter plotted along one axis and time or any other independent parameter plotted along the other axis. The analysis of such data was till recently done manually. But when the volume of data increases it is advantageous if we mechanise the analysis. Now, Digital Computers are being used for analysis of such data. The digital computer accepts only discrete numbers as inputs and the data we obtain has to be in digital form or we have to convert it to digital form.

Generally data cannot be otained in digital form since:

1. Digital recording instuments are still costly as compared to analog instruments, and
2. Since we have to check the data before it is processed,it

is better to have data in a form that makes checking easier. Visually checking analog records is easier than checking digital data.

The fact that analog recording equipment is cheaper is an important factor when there are several field installations. The analog records can in such a case be converted to digital form at a central location.

Some fields where such line record to digtal information conversion is required are in Radio Propagation studies, Electrocardiogram and Electroencephalogram Analysis.[1]

Data obtained from Radio propagation measurements is frequently recorded on strip chart.[2] Typically propagation records might show received signal strength as a function of time. Such records are analysed to extract, for example, the statistical cumulative distribution of signal strength as against percentage of time. Alternately, the correlation between signal strengths at two receiving stations or between signal strength and meteorological parameters may be required.

Another field where such a system may be of use is in the analysis of bioelectric data such as Electrocardiograms and Electroencephalograms.[3,4] Suffice to say that, because of the steps an electrocardiographer goes through, in recognising and measuring the parameters in an Electrocardiogram

involves a large number of logical decisions, and because the digital computer can be programmed to carry out these logical decisions, it is advantageous to use a computer for the analysis.

Now, converting the ordinates of a recording to digital values manually is laborious and the method is prone to errors. Manual transduction has been carried out for this purpose, where one manually follows the recorded ink line. In such a system, since the output voltage corresponds to the position of the follower head one must be careful in following the trace. This work is also troublesome and time consuming.

This project was taken up for developing an automatic means of picking up the recorded ink line as against the co-ordinate backgound and to obtain a signal proportional to the position of the ink line along the ordinate. this analog voltage is subsequently converted to a convenient digital form which is stored on magnetic tape.

CHAPTER II

SPADEWORK

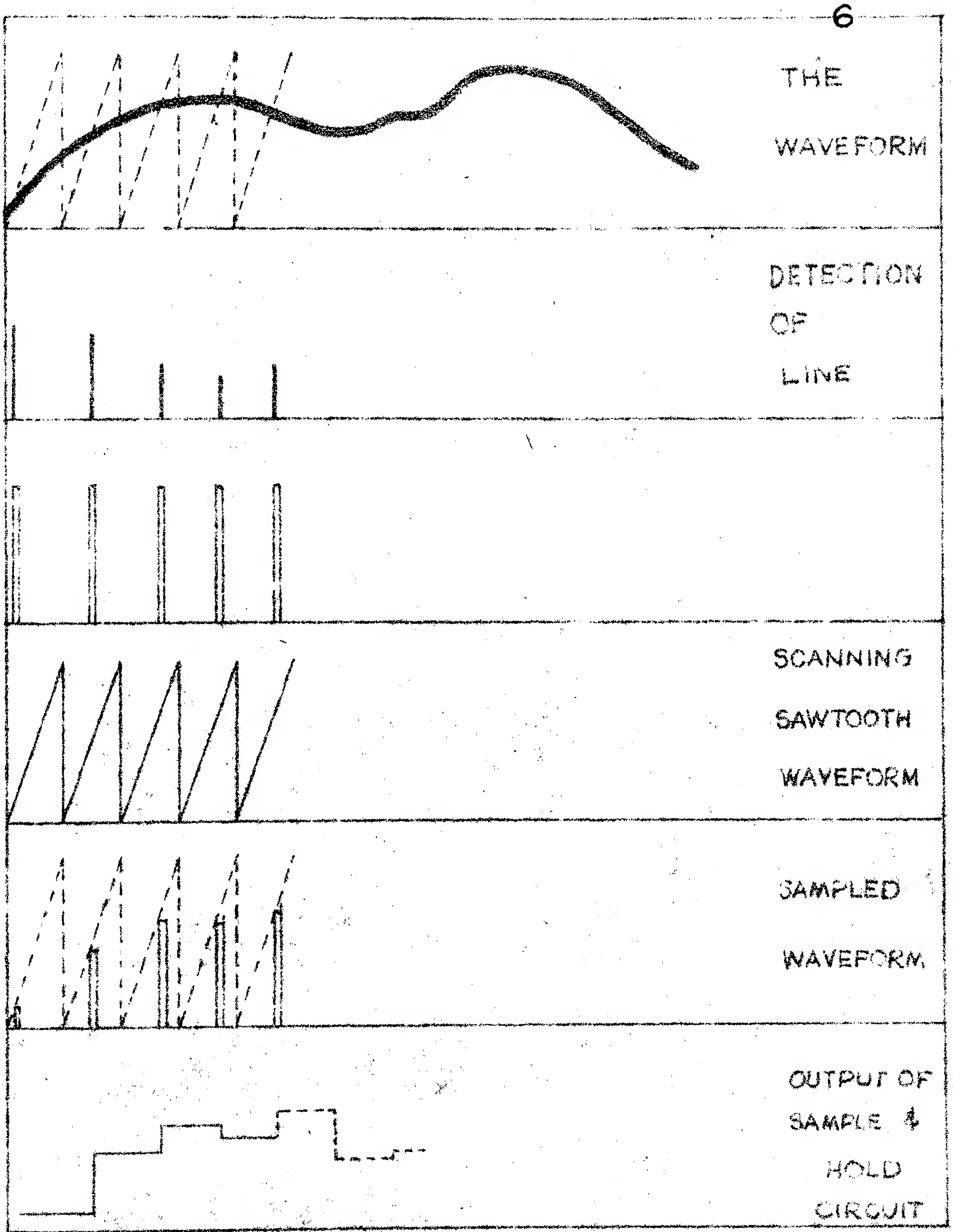
Previous attempts

Systems have been developed to convert complex records to digital format. They all differ in the method of scanning and the degree of sophistication in electronics. One of the common systems makes use of a sawtooth waveform to scan the record in the y-direction, and an identical sawtooth is the input to a sample and hold circuit. Whenever during a scan the line on the record is sensed the corresponding value of the sawtooth is sampled and the voltage held in a capacitor. See Fig. 1. There is time till the arrival of the next sample in which Analog to Digital (Ato D) conversion can be done. One of the advantages of the Sample and hold scheme is that because of the hold, a break in the line does not cause any difficulty. Some other attempts are restricted to manual transduction, the digitisation being done by various means; by conducting patterns that give numbers in the "Grey code", shaft encoders etc. Outputs of linear potentiometers are also used the voltage thus obtained is then subjected to an AtoD conversion.

Preliminary Considerations

Some of the aspects considered were:

1. Whether the curve follower method was preferable to scanning ?
2. Whether to choose a strip chart recorder or a X-Y recorder



SAMPLE & HOLD SCHEME

to rerun the record for conversion ?

3. What should be the precision in sampling ?

4. What proceedure should be followed to separate the recorded line from the co-ordinate lines ?

5. How should the analog voltage be converted to digital information and how should this be stored ?

Solutions

1. Curve follower method has certain disadvantages. There would be difficulties when discontinuities and steep slopes are encountered on the curve. The speed of follow up has to be slow since one has to allow the follower head to settle down on the line. Also the system has to be started off with the tracking head on the line. Scanning overcomes some of these difficulties; the scanning speed is ofcourse limited by the inertia of the scan head.

2. Quite a lot of analog data is usually on strip charts. It would therefore be more logical to rerun records on such equipment for digitising purposes. The difficulty in choosing a strip chart recorder for such purposes is that the recording pen is on a galvanometer movement, and is necessarily very light in weight. Since the scanning head would have atleast a source of light, a light sensitive cell and associated lens system, it would all be relatively heavy for placing on a galvanometer movement. In an X-Y recorder on the other hand the recording pen is on sturdier foundations and a scanning head

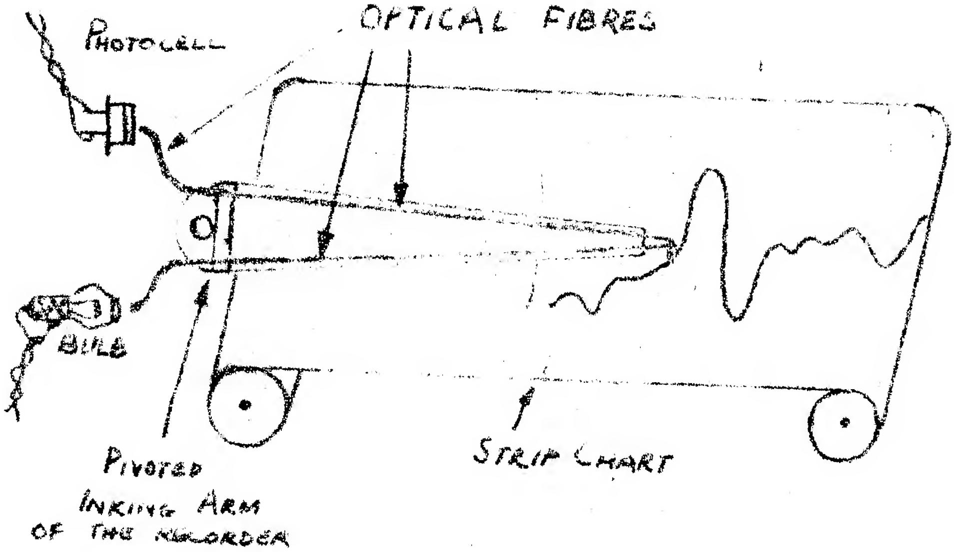
as above can be easily accommodated.

Recent developments in fiber optics can enable us to have a scan head that is light in weight. The source of light and the photo cell need not be mounted on the scanning arm.[5] Two light bundles one carrying light from the source to the paper and the other the picked up light from the chart to the photocell, can be attached on the scanning arm. Fig. 2

The use of X-Y recorder is not all that inhibitive since attachments are now available to convert existing X-Y recorders to strip chart recorders.

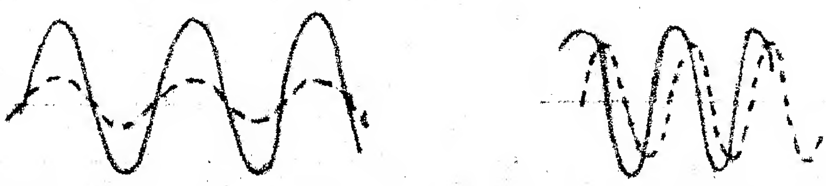
3. Sampling rate has naturally to be such that the digital output contains all the information that is contained in the original recording. Sampling rate can safely be taken as twice the highest frequency component only when the coding is optimum. When the coding is not optimum difficulties as illustrated in Fig. 2 will arise. To avoid the need for optimum coding the sampling rate is usually made five to ten times the highest frequency component of the signal.

4. There have been previous attempts at picking up the recorded line from the coordinate lines. Notably that of Carson,[6] who uses a reference chart which is scanned along with the main chart and by subtracting one signal from the other, eliminates the signal due to the coordinate lines. Such measures will have to be resorted to only when the ink



Optical fibre used for picking-up the line

FIG. 2



Cases where the coding is not optimum

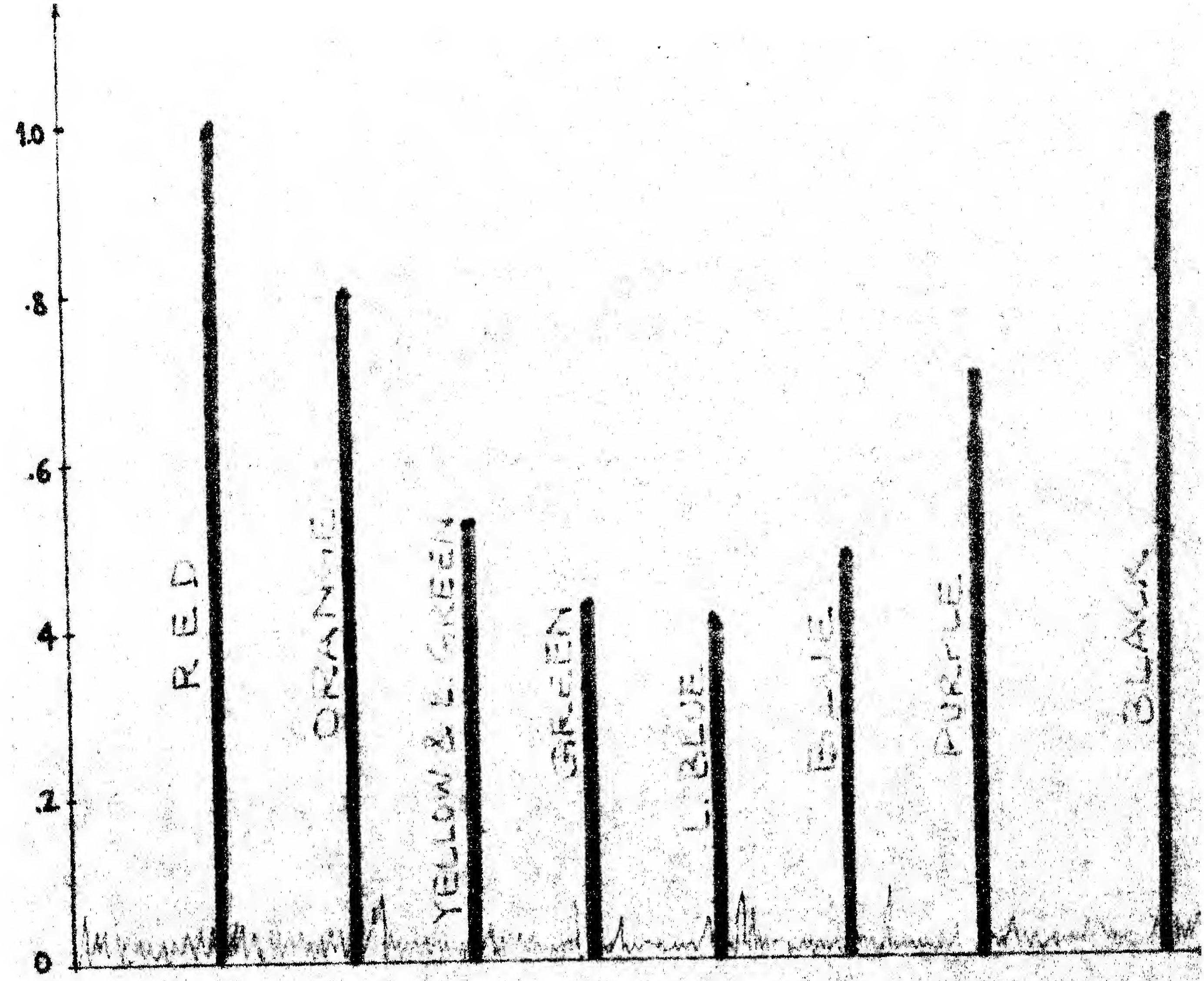
FIG. 3

line and coordinate lines are of exactly the same colour and hue, or are very nearly so.

The method adopted herein, uses the colour discrimination property of the CdS photocell. When Violet, Black or Red inks are used on light green or light blue coordinate background, the discrimination is adequate.[2] See Fig. 4

5. The method used in scanning, and converting the y displacement of the ink line to digital information, is discussed in the next chapter. A convenient medium for storing the data is the magnetic tape.

If one records data in a fashion that is compatible with the tape units of the existing computers, the data can be directly made available to the computer from the recorded tape.



NOTE DISCRIMINATION BETWEEN RED & BLACK ON ONE HAND AND BLUE & GREEN ON THE OTHER

COLOR RESPONSE OF CdS CELL

CHAPTER III

THE WORKING SYSTEM

The system is essentially built around an X-Y recorder Mosely Model 135. Such a recorder does not have to be permanently attached to the system and need be introduced only just before the system is to be used for conversion of records. Also, the make and type of the X-Y recorder is relatively unimportant. The system can be set up, without much difficulty using any standard X-Y recorder. For general specifications of such a recorder see Appendix, A.

<u>Description of the working of the system</u>

The graph to be digitised is placed on the flat platten of the recorder with care being taken to see that it is really flat. The graph has to be less than 25 cms. by 12 cms.. The scanning in the y-direction is done by a voltage that is proportional to the count in a seven bit counter. Hence, for each position of the scanning head there is a proportional value in the counter. After every scan in the y-direction,an increment is made in a set of x-diretional counters. This causes a proportional voltage to displace the scanning head in the x-direction. During the scan, when the recorded line is encountered the light falling on the photoconducting cell diminishes, causing a change in the cell resistance. This change causes the detection of the line. The signal generated

when a line is detected is used to gate the value of the y-counter into a register. In this way at the end of every scan we can find in the register a binary number proportional to the position of the recorded ink line at that particular abscissa. We shall now discuss the individual blocks of the block diagram; Fig. 5.

<u>ElectroOptical System</u>

A pencil beam of light is shone on the record and the reflected light is imaged by an achromatic convex lens on a photoconductive CdS cell, (GE-B-425). The cell resistance increases when the light falling on it decreases. This change is essentially the means of detecting a dark line.

A pencil beam of light is obtained using miniature pencil torch bulbs, 2.2 V 200ma., that have a lens mounted on the bulb itself. These bulbs give more light than even 12 volt bulbs since the light is concentrated in a beam. Also, weight considerations limited the choice to torch bulbs rather than some other form of lighting. Another advantage is that these bulbs are easily available in the market. The amount of light emitted by the bulb varies directly with the square of the supply voltage and this voltage has therefore to be well regulated. Dry cells can be used; an independent regulated supply is desirable, but would be an added cost.

The resolution of the system depends to a great extent on the optical head. the lens is so positioned that it is

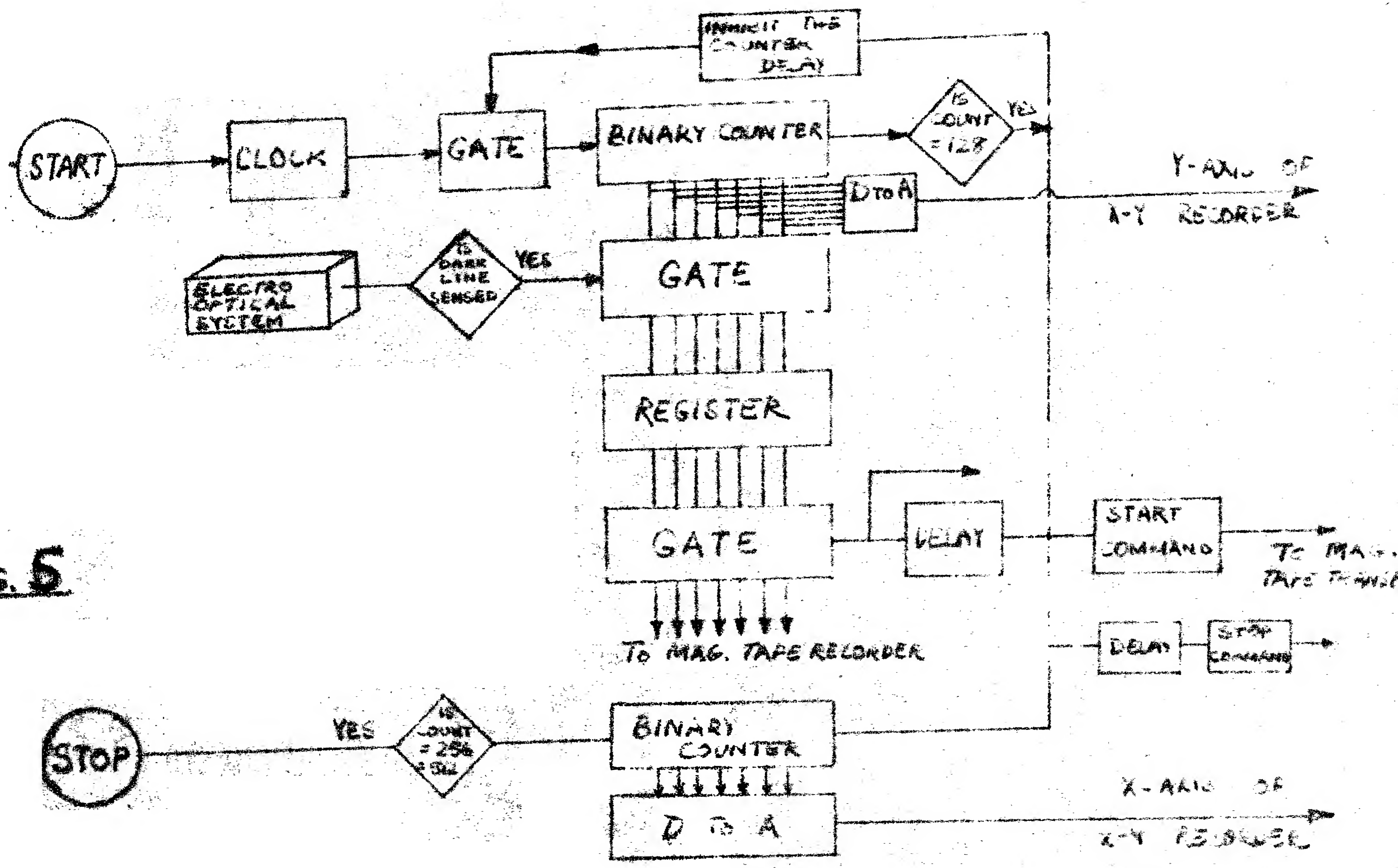

START
CLOCK
GATE
BINARY COUNTER
IS COUNT =128
YES
Y-AXIS OF
X-Y RECORDER
D TO A
ELECTRO OPTICAL SYSTEM
IS DARK LINE SENSED
YES
GATE
REGISTER
GATE
DELAY
START COMMAND
DELAY
To MAG. TAPE RECORDER
STOP
YES
BINARY COUNTER
D TO A
X-AXIS OF

Fig. 5

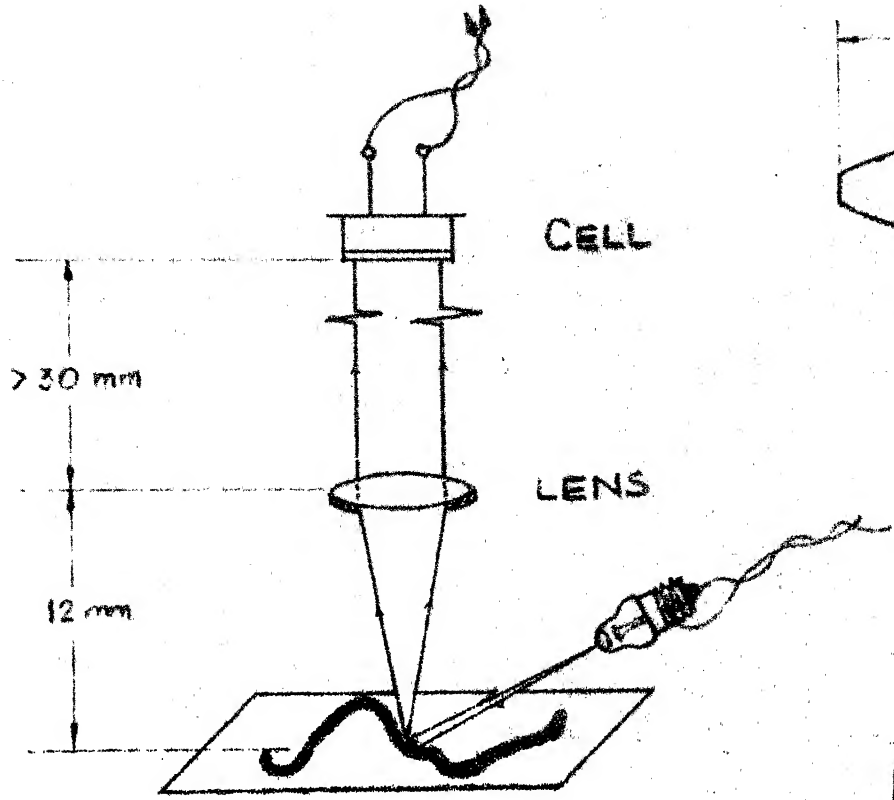
at a distance of a focal length from the record. This means that light rays from a point on the record after passing through the lens will be a set of parallel rays, that is, the image of the point would be at infinity. Fig. 6

It is advantageous to have a shutter with a small aperture very near the record surface. (Fig. 6 b.) However it is not easy to provide for this because of the problems of illuminating the record. The resolution in the y- direction becomes less important when multiple valued functions are not considered.

The change in photocell resistance when the dark line line is encountered is converted to a change in voltage and is amplified using an FET amplifier. The output of the FET amplifier is connected to the input of a Schmidt trigger. A 10 volt puse is generated by the Schmidt trigger whenever a line is detected. See Appendix B.

Scanning and obtaining of Digital information

The aim herein is to obtain a digitised quantity proportional to the distance of the recorded line along the y-direction.



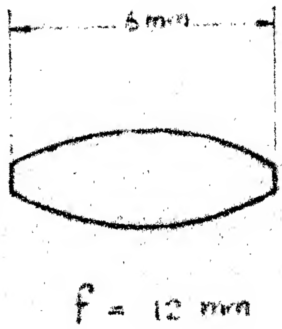
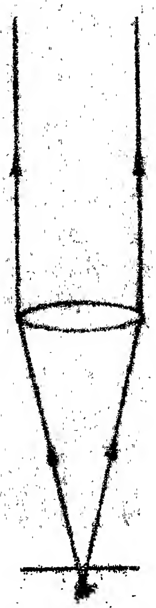


FIG.

Fig. 6 a.

LINE DIAGRAM OF THE OPTICAL-SYSTE

Fig. 6 b



APERTURE NEARER

We could get a voltage that is proportional to the displacement of the scanning head along the y-direction and convert this voltage to a digital quantity. A common method of A to D conversion is to generate a linear ramp which is clamped when it is equal to the analog voltage. During the interval that the ramp voltage is increasing a train of pulses is gated through. The width of the gate, and hence the number of pulses gated through, would be directly proportional to the analog voltage. Counting the number of pulses that are gated by the ramp, gives a digital number proportional to the analog voltage.

The scanning rate has to be decided bearing in mind the response capability of the X-Y recorder. Best performance of such mechanical instruments is below ten radians per sec. It is preferable not to increase the scan frequency much above two cycles per second.

An AtoD conversion scheme as outlined above was tried out and later abandonned because, generating a slow linear ramp posed problems. A simpler and better method is available and was used.

The method adopted was to use a seven bit counter (count of 128) to serve for both getting the digital information and also the analog votage to drive the scanning head. The counter content is converted to a proportional analog voltage, using a simple analog conversion (Digital to Analog) technique that involves a ladder network of

resistors. See Appendix C. 1% tolerance resistors were used and the evenness of the steps was checked on a Storage Scope. (Tektronix 564). Since the analog voltage for driving the scanning head was obtained from a counter, digital information proportional to the y-directional displacement of the head, is always available. And this has to be only interrogated (using the output of the optical system) when a line is actually detected to know the digital value of the displacement along the y-direction. Whenever the line is detected the y-directional counter contents are gated into a seven bit register made up of flip flops.

At the end of the scan some time is to be given for the scan head to return to the base line before the next scan begins. This delay is acheived by gating the clock pulses through a gate, which is opened for a specific length of time by a monostable multivibrator. During this delay the X-directional increment is also carried out. The x-drive is also by a voltage derived from a D to A conversion of the contents of a x-directional counter. Here a count of 256 or 512 can be employed depending on the accuracy desired. Details regarding the flip flops and latter network for D to A conversion are in the Appendix. C & D.

At the end of each scan a read pulse can read out the contents of the register and we have a digital quantity proportional to the displacement of the line along the y-ordinate.

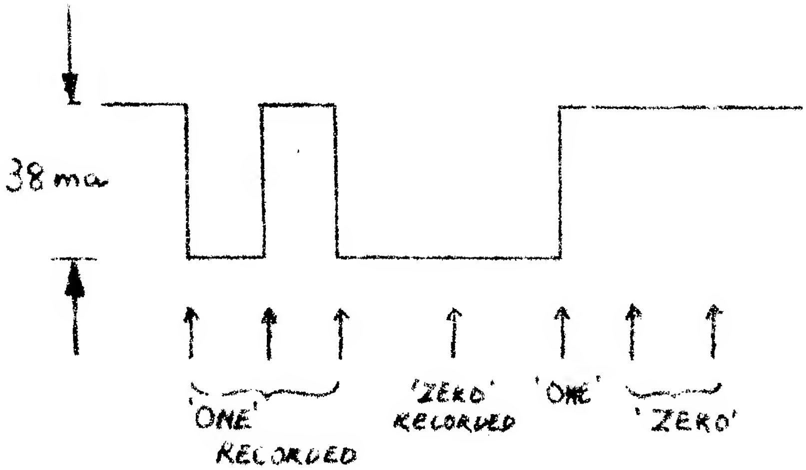
CHAPTER IV

MAGNETIC TAPE RECORDING

The digital data obtained from the system has to be stored for subsequent computer analysis. For this purpose magnetic tape was thought to be the best medium for storage. The magnetic tape on which data is stored can be directly used as the source of data when computer processing has to be done. When the data is to be processed by the computer the recording has to be in such a manner as to be compatible with the type of computer being used.

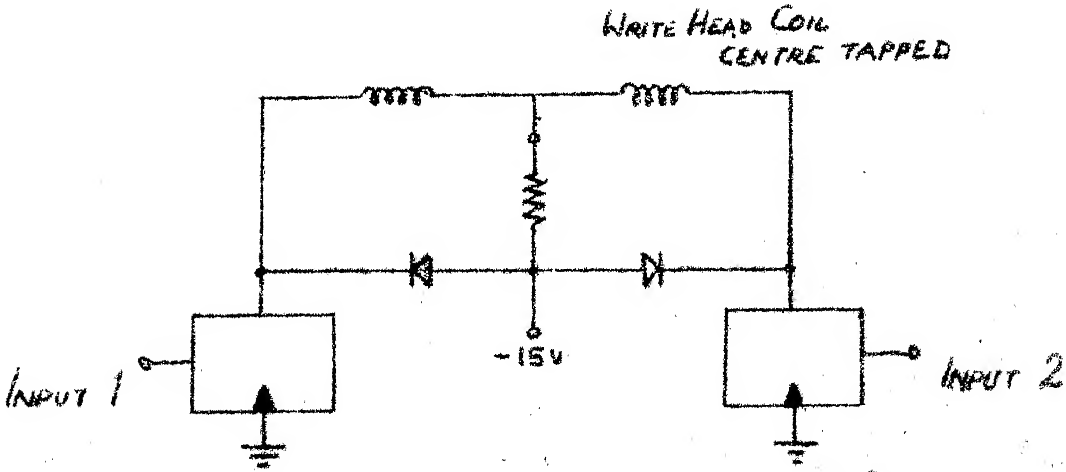
The recording has to be, in our case, IBM compatible. IBM uses NRZ I scheme of recording (Non return to zero IBM). When current flows through the recording head coil, the magnetic oxide particles on the tape are oriented in one direction. If the current in the coil reverses its direction the particles on the tape will be oriented in the opposite d direction. In the NRZ I method a '1' is stored by a reversal of flux polarity and a '0' by the absence of such a reversal. In this system therefore, the magnetic tape is fully mgnet magnetised in each track, and the polarity is reversed as each one bit is written. See Fig. 8

The write heads of the tape unit are centre tapped so that the magnetising field can be reversed by grounding the opposite sides of the head. This can be done by connecting the driver to the opposite sides of a flip flop. When



NRZ·I RECORDING

FIG. 8



Depending on the inputs 1 and 2 the current in the coil will be from right to left or left to right.

FIG. 9

the flip flop is complimented the current direction changes and a '1' is written. To record a '0' the current direction in the write head is not changed. Fig. 8,9.

The recorder intended to be used is a Potter MT-36, which is IBM compatible. Six bits of the seven tracks form the data and the seventh is the parity bit. Data is represented on the magnetic tape by the use of either the binary coded decimal (BCD) code or just the binary code. In our case the register contents are in binary and hence it can be directly recorded. Binary coded tape may either have odd parity or may have even parity, but generally odd parity is used. Parity bit is usually written using a pyramid of exclusive ORs. when the recorder itself does not provide the parity bit.

In our case since there are seven bits of information the data has to be written in two characters on the tape. The information is recorded in a special format.

First Character	Second Character
1	1
7	3
2	2
0	0
6	2
2	2
5	1
2	2
4	0
2	2

An IBM 7044 word consists of 36 bits which on the tape

will occupy six characters each of six bits. Since we have more than six bits of information it is easy to see that we need space of two characters. Every computer word consists of six characters while our information consists of two characters. therefore every computer word consists of three sets of information that is supplied by the digital conversion system. A program had to be written to unpack one computer word into three words and to store them in successive locations. Also since the recording is in a special format a little manipulation is required to assemble the number before it is stored. The program is given in Appendix E.

The time of a y-scan is about two seconds and information to be written on tape is available only once in about two seconds. Leaving the tape to run continuously while recording once in a while, would cause a lot of wastage of tape and the packing density would be low. Hence, at the end of every scan the tape unit is started and after a finite delay the contents are written on the tape (contents of the register). The tape is then stopped. This increases the packing density. Starting and stopping of the tape will cause a certain length of blank tape to come in between consecutive recordings of data. This blank tape may constitute inter-record gaps. We may then have to treat every recording as a separate record. In our case such a problem will not arise since the starting and stopping time in the Potter recorder are pretty small. See Appendix F.

The motion of the Potter MT-3 tape transport unit can be controlled externally by giving suitable voltages at the pins of connector J 102 . See Appendix G.

At the end of every scan a start pulse is given to the tape transport. After a specified delay the contents of the register have to be written on tape. Immidiately a stop command stops the tape transport mechanism.

By the program referred to earlier one can get the data printed out. These numbers would correspond to the displacement along the y-direction of the recorded line. The data thus obtained can be used to analyse the original recording.

CONCLUSIONS

It is possible using a Cd-S cell to discriminate between the coordinate background and a dark red or black line. The discrimination is best when the coordinate background is either light blue or light green.

The scheme of using counters to derive the analog voltage which drives the scanning head, is simpler, better and cheaper than other commonly used systems. A typical system uses linear potentiometers and Ato D converters. These schemes are therefore more expensive and complex.

There are 128 levels of quantisation in the y-direction and 256 (or 512) levels in the x-direction. The latter corresponds to 20 (or 40) samples per cm. of the record. The speed of scan is limited by the response characteistics of the X-Y recorder. The time for one scan is about 2 seconds and the system performs best at that speed or lower speeds. Having lower speeds for scanning has the disadvantage of the system needing more time to digitise a record.

Since a lens system is used in the scan head, and the paper is to be at a distance of one focal length from the lens, it is important to ensure that the paper is absolutely flat on the platten. Where vacuum hold down of the paper does not exist one may even have to stick the paper on the platten with glue.

This much care would not be required if in the scan head optical fibres are used instead of the lens system. The optical head that uses optical fibres is discussed in Chapter II of the text.

An incremental tape recorder with IBM compatible scheme of recording would be the best medium for storing the data. Line records can then be analysed advantageously using digital computers.

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APPENDIX A

GENERAL SPECIFICATIONS FOR X-Y RECORDER

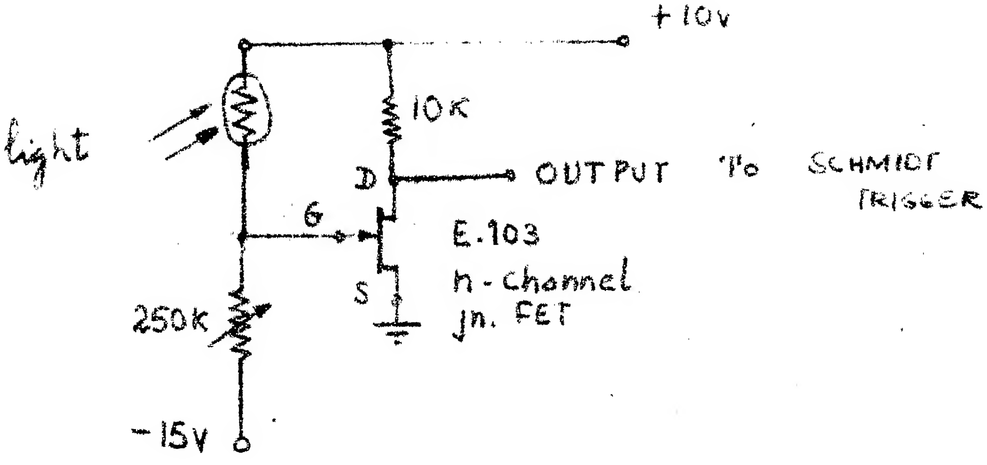
Operation on Supply Voltage		220-250 Volts.
	Frequency	50 Cycles
Built in amplifiers for both X and Y inputs.		
Minimum Sensitivity	X direction input.	0.2 Volts/inch.
	Y direction input	0.2 Volts/inch.
Response time	better than	2 cycles/sec.
Linearity	better than	0.1 %
Preferable	adapter to convert to Strip chart recorder.	

APPENDIX B

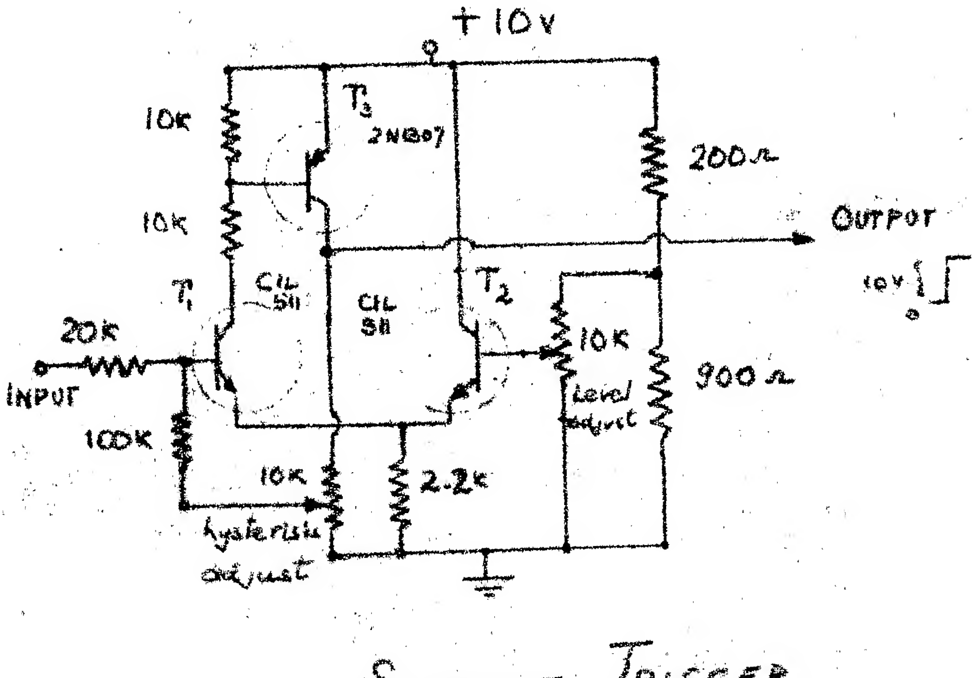
FET Amplifier

The photocell resistance is about 100 K-ohm with the bulb voltage at 2.2 volts and the aperture as at present. the potentiometer is adjusted to give a voltage of about 2 V. at the terminal D. See Fig. 10 . When this is so the FET is biased near its cut-off region. $V_{GS} = -2.5$ volts. When the light falling on the cell decreases, the cell resistance increases. To about 115 K-ohm for a 1mm. thick black line.

Even a change of 10 K-ohm produces a voltage change at G equal to $\frac{10 \times 25}{210}$ which is greater than 1 volt. This



FET AMPLIFIER



SCHMIDT TRIGGER

FIG 10

drives the FET to cut off and the voltage at D rises towards 10 Volts. The output of this stage is fed into Schmidt trigger which gives a clean step when the input voltage rises above a preset level.

<u>Schmidt Trigger</u> See Fig. 10

If we set the level adjust at say 5 Volts, then until the input voltage increases above 5 Volts T_1 does not conduct. When T_1 is not conducting the output voltage is zero as T_3 is also not conducting. When the input rises above 5 Volts T_1 and hence T_3 starts conducting. T_3 saturates and the output is 10 Volts. Because of positive feedback to the base of the transistor T_1 , the transition is swift. Similarly when the input falls below the set level, the output drops to zero. The hysterisis adjust is the control of this positive feed-back and determines how soon the output will return to zero after the input falls below the reference.

The Schmidt trigger in our system gives a 10 Volt pulse whenever the dark line is encountered during the scanning operation.

APPENDIX C

D TO A LADDER CONVERSION

See Fig. 11 . If all the flip flops are in the '1' state then the voltage at A would be :

By Superposition theorem let us calculate the required quantity by setting each flip flop at '1' state with the rest at '0' state. The sum of all such voltages at A gives us the required value.

Voltage at A when flip flop 2^6 is in the '1' state all others are in the '0' state. — $\frac{V_{FF}}{3}$

Voltage at A '' '' 2^5 " " " — $\frac{V_{FF}}{3} \times \frac{1}{2}$

2^4 $\frac{V_{FF}}{3} \times \frac{1}{4}$

"

"

2^0 $\frac{V_{FF}}{3} \times \frac{1}{64}$

Therefore $E_A = \frac{V_{FF}}{3}\left\{1 + \frac{1}{2} + \frac{1}{4} + \cdots + \frac{1}{64}\right\} = \frac{V_{FF}}{3}\,\frac{127}{64}$

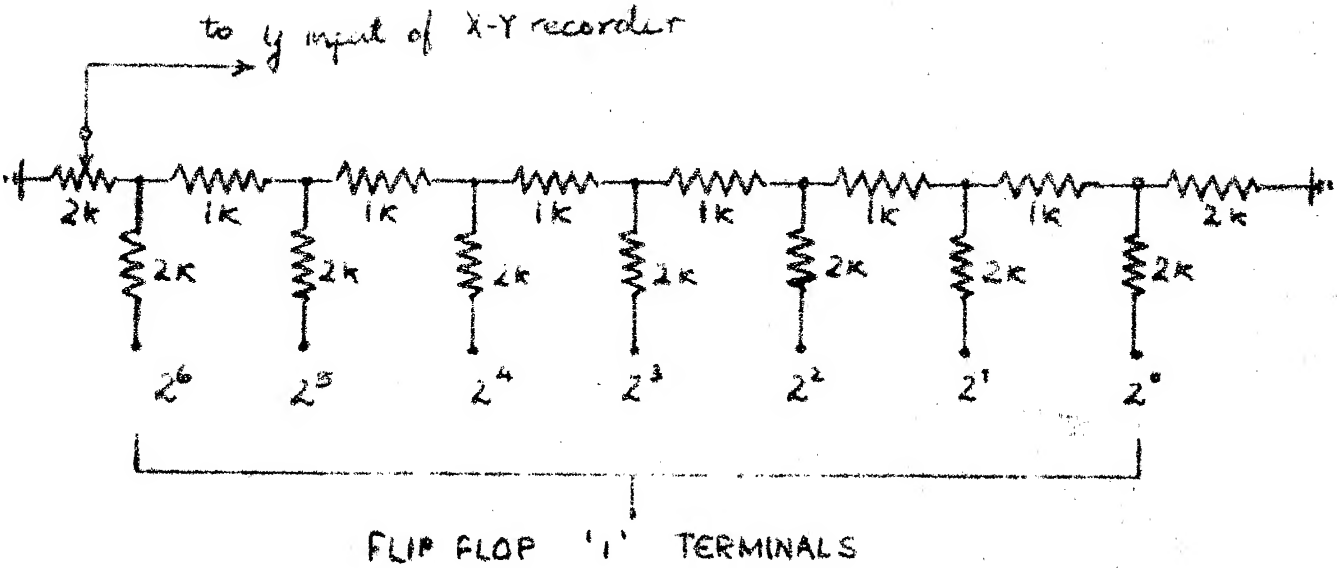
when alll flip flops are '1'. $= \frac{2}{3} \times V_{FF} \times \frac{127}{128}$

In general $E_A = \frac{2}{3} \times V_{FF} \times \frac{1}{2^n} \times p$

where V_{FF} is the voltage level of flip flop in '1' state with '0' state being at 0 Volts.

n is the number of flip flops, and p is the count $= a_0 2^0 + a_1 2^1 + \ldots + \ldots a_{n-1} 2^{n-1}$

so when $n = 7$; $p = 127$.



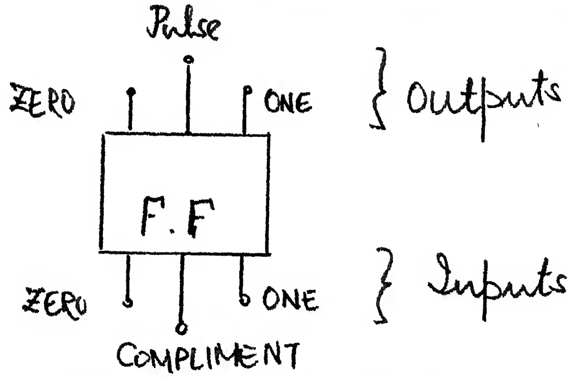
D TO A LADDER CONVERSION

FIG. 11

APPENDIX D

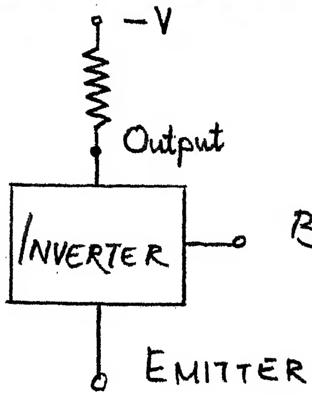
FLIP FLOP SPECIFICATIONS

Levels	'1' state	- 3 Volts.
	'0' state	0 Volts.
Input	Compliment input optional level inputs '0' and '1'.	
Pulse output	- 2.5 Volt; 0.4 μsec	
Fan in Fan out	about four similar stages	



INVERTER SPECIFICATIONS

Base input	pulse -2.5 Volts. 0.4 μsec.
Emitter and Output levels	0 and -3 volts.



APPENDIX E

COMPUTER PROGRAM

The analysis etc. can be done conveniently in Fortran and so the numbers we are interested in are made available by a Fortran CALL Statement. The CALL statement shown in the segment of a Fortran program shown below gives access to a MAP subroutine given in the next page. This MAP subroutine is the Packing - Unpacking program referred to in the text.

```
      DIMENSION LOCDEC(4096),CHECK(300)
      INTEGER CHECK
      CALL READIP(4,17,LOCDEC)
      WRITE(6,10)(LOCDEC(J),J=1,51)
   10 FORMAT(16I8)
       STOP
       END
```

```
$IBMAP           NODECK
        ENTRY    READIP
READIP  SAVE     1,2,4
        CLA      =1168      DEC. ADDRESS OF TP UNIT ZERO, ON CH.B
        ADD*     3,4
        STA      RDSIP
        CLA*     4,4
        STA      LOCD.1
        ALS      18
        STD      IORDIP
        CLA      5,4
        ADD      =2           TO GET THE LOCATION LOCDEC+2
        STA      INID.1
        STA      STQDEC
RDSIP   RDS      **
        RCHB     IORDIP
        TCOB     *
IORDIP  IORD     BUFFIP,,**
        CLA      IORDIP
        ADD*     4,4
        STA      LOCD.2 STORE BUEFIP+RECRDLNGTH/IN LOC LOCD.I
INID.1  CLA      **         TO BE USED FOR INITIALISATION
LOCD.1  AXT      **,1
LOCD.2  CLA      **,1
        AXT      3,2
LOCD.3  LDQ      ZERO
        LGR      3
        ARS      1
        LGR      1
        ARS      1
        LGR      3
        ARS      1
        LGR      1
        ARS      1
        STO      TEMDEC
        ZAC
        LGR      28
STQDEC  STQ      **
        CLA      STQDEC
        ADD      =1
        STA      STQDEC
        CLA      TEMDEC
        TIX      LOCD.3,2,1
        CLA      STQDEC
        SUB      =6
        STA      STQDEC
        TIX      LOCD.2,1,1
        CLA      INID.1
        STA      STQDEC
        RETURN   READIP
BUFFIP  BSS      1400
ZERO    DEC      0
TEMDEC  BSS      1
        END
```

APPENDIX F

TAPE TRANSPORT SPECIFICATIONS

POTTER MT-36

Tape speed	30 and 36 inches/sec. (ips)
Tape speed tolerance	1 %
Rewind time	less than 3 mts for 2400 ft. of tape.
Start Distance	0.085 0.02 inch within 5 msec. after RUN command at 36 ips.
Stop Distance	0.03 0.015 inch at 36 ips.
Stop time	less than 1.5 msec.
Distance in one Start Stop cycle	less than 0.132 inch.
Wow and flutter	less than 1% RMS at 36 ips.
Interchannel time displacement at 36 ips.	Static 8 µsec. max. Dynamic 3 µsec. Total 11 µsec. max.

APPENDIX G

MT-36 TAPE TRANSPORT CONTROL

		INPUT AT J-102	PLUG INPUT
RUN/STOP	-5 V. d.c. run 0 V. stop	A	B
REV/FWD operates in conjunction with NORMAL /HIGH speed inputs at pin G.	-5 V. rewind 0 V. forward	B	I
NORMAL/HIGH Speed.	-5 V. high speed	G	D
-5 V when tape transport is in reverse mode		N	F
-5 V When tape transport is in forward mode		P	G
-10 V Auto indicate line		Q	C
-5 V low speed 0 V high speed		I	D
Write lockout switch normally closed		Y	A
" " open		Z	H

INPUTS THAT ARE AVAILABLE TO US